Indoor Air Quality – An outline of CIBSE guidance

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Maintaining appropriate indoor air quality is not just a challenge for the building services engineering practitioner but also excites increasing interest in government, the general public and the media.

However, there is no simple measure for IAQ as it is a potpourri of parameters that are influenced by the external and adjoining environments as well the activities and construction of the internal space. Common factors that contribute to the assessment of IAQ are volatile organic chemicals (VOCs) such as formaldehyde, and other gases including carbon dioxide and carbon monoxide, ozone, nitrogen dioxide water vapour and radon; particulate matter (for example 'black carbon' from incomplete combustion that are a significant source of PM2.5) and fibres; and biological components including bacteria, fungi (such as mould) and pollen; and 'odours'.

In terms of the building occupant these are all combined with their personal perception of the internal environment that will be influenced by the more traditional measurands of comfort (such as temperature, air movement, noise and light). However, the consequences of poor IAQ, may not actually affect perceived comfort but can lead to loss of productivity, ill health, disease and potentially premature death.

IAQ pervades many areas of CIBSE technical information – some of the principal CIBSE references are discussed in the following briefing note.

- **CIBSE Guide A (2015) 'Environmental Design'**

Chapter 0 identifies that one of the main criteria for building environmental design decisions is health that is related explicitly to indoor air quality. Chapter 1 goes on to set the primary comfort criteria and indicative air supply rates (in table 1.5) but defers the detail of IAQ to later chapters. Section 1.8.4 introduces ventilation effectiveness to predict how a given rate of ventilation will dilute and remove pollutants for a particular air distribution pattern. Chapter 4 Section 4.2.1 provides an indication of the basic ventilation rates (in $L \cdot s^{-1}$ per person) that are related to the EN 13779 categories of IDA 1 - high indoor air quality, through to IDA 4 - low indoor air quality. This chapter also includes recommendations for specific spaces in dwellings and offices (most of which are derived from the UK Building Regulations) and an extensive list of references for ventilation requirements in other spaces (such as call centres, cleanrooms and prison cells). The classic 'pollution concentration equation' is introduced in Sect. 4.2.3 that can provide useful, but simple, insight into the potential ventilation capacitance of a space as a means of controlling levels of transient pollutants – it is applied with an example of occupant CO_2 emissions and polluted outdoor air. The end of chapter 4 introduces the opportunity for computational fluid dynamics (CFD) to explore IAQ that is slightly expanded in chapter 5, section 5.7.2 where zonal network methods are also introduced as a potential investigative tool.
Chapter 8, section 8.4 holds the core IAQ commentary and provides typically required fresh air supply rates to maintain acceptable CO_2 levels. There is introductory material on indoor

pollutants and their health (and sensory) effects with links to the relevant occupational exposure limits. A notable table 8.3 indicates the influence of poor system practices, such as unclean ductwork, on occupant respiratory symptoms. This section considers the importance and impact of outdoor air and the typical relative pollution of the 'fresh' air and the internal space and the required filtration is discussed as a means of moderating the impact of poor outdoor air quality. The chapter concludes with a brief discussion of the impact of IAQ on sickness and productivity.

- **CIBSE Guide B0 (2016) 'Applications and activities: HVAC strategies for common building types'**

Mechanical ventilation systems are introduced as being a means of improving IAQ by delivering 'adequate clean supply air' but in section 0.5.7, earlier concerns are reiterated, that the systems can be detrimental to IAQ when not maintained appropriately.

- **CIBSE Guide B2 (2016) 'Ventilation and ductwork'**

Despite including the contested design, build and operating costs ratio of 1:5:200, the argument is still strong that poor indoor air quality impairs the performance of occupants. In section 2.2.2 contaminant control is considered with some expanded reiteration covering indoor and outdoor pollutants. In particular, it clarifies that the ventilation rates derived from EN 13779 relate to comfort air quality and do not necessarily reflect that health-related requirements. Where natural or passive cooling is used section 2.2.4 indicates that the ventilation rate will surpass that needed for IAQ. The air distribution section 2.2.8 discusses the different ventilation modes including the impact on IAQ and section 2.3 moves on to systems where it notes that 'the maintenance of air quality may often require air cleaning methods'. Later it comments that the much quoted 'openable area equivalent to 5 per cent of floor area' does not necessarily satisfy requirements for special air quality needs but reiterates that indoor air quality can be moderated using the reservoir effect provided by the volume of the space. Displacement air supply systems are noted as potentially delivering improved air quality over those that rely of 'mixed air' dilution. The section provides extensive comparisons of the pros and cons of natural, mechanical and mixed-mode ventilation – including a useful decision chart for mixed-mode ventilation systems.
Section 2.3.3 introduces filtration and provides some detailed information on contaminants and the opportunity to effectively control them in ventilation systems with appropriate filter types noting that the available guidance on external air quality is subject to 'periodic review'. Methods of delivering ventilation air are discussed with a final section on maintenance that includes specific commentary on 'air quality and health issues'.

- **CIBSE Guide B3 (2016) 'Air Conditioning and Refrigeration'**

Draws on other sections of the guide but notes that occupants' perception of the effectiveness of the system will normally be influenced by the air quality in the breathing zone and that systems that have higher airflow rates and little or no recirculated air are likely to promote good IAQ.

- **CIBSE Guide F (2012) 'Energy efficiency in Buildings'**

Notes that the potential for improved air quality can be synonymous with low-energy buildings and in the later design section explicitly states that the object is to deliver acceptable indoor air quality with the minimum use of energy. It continues with a methodical examination of ventilation modes to efficiently deliver appropriate conditions with particular emphasis on controlling minimum fresh air to maintain air quality including a concluding discussion on demand controlled ventilation.

- **CIBSE Guide G (2014) 'Public Health Engineering and Plumbing'**

Includes a section on green roofs that are noted as providing air quality improvements amongst other benefits.

- **CIBSE Guide H (2009) 'Controls'**

Indicates that although the primary function of a building control system has been the control of temperature and humidity, the increased awareness of sick building syndrome (SBS) and other building related illnesses has emphasised the requirement to ensure good indoor air quality. Section 3 includes an overview of controlling ventilation for air quality and includes some basic information on the application of sensors although it later, in section 5.7, admits that at the time of publication (2009) there was no reliable measurement which would allow automatic control of ventilation for indoor air quality. Control strategies are included for dealing with poor outdoor air quality with the warning that an indoor IAQ sensor which controls ventilation rate may react to any ingress of outdoor pollutants by increasing the ventilation rate and so making the situation worse. There is a whole chapter dedicated to air pollution in the (now withdrawn).

- **CIBSE Guide J (2002) 'Weather, solar and illuminance data'**

Provides a more extensive commentary on the effects of pollutants than is provided in other sections of the CIBSE Guides.

- **CIBSE Guide L (2007) 'Sustainability'** (currently under revision)

Links elevated temperatures (due to climate change) to potentially increased outgassing of pollutants (e.g. VOCs) from structure and furnishings affecting IAQ. However, the majority of air quality aspects considered in Guide L are focussed on the secondary impact of systems such as CHP, boilers and insulation materials and refrigerants.

- **CIBSE Guide M (2014) 'Maintenance engineering and management'**

Section 16.1 of focuses on maintaining appropriate IAQ with a brief commentary of monitoring the sources of contaminants. It recommends that air quality indicators be routinely reviewed, to assess seasonal variations and to confirm the validity of any initial assessments.

- **CIBSE AM10 2005 'Natural ventilation'**

Sets out by defining that natural ventilation systems are intended to provide sufficient outside air to maintain IAQ standards and in section 2.1.1 includes illustrations of the efficacy of different natural ventilation strategies on air quality (using CO_2 as a proxy). The applications throughout the Guide are led by IAQ considerations noting the importance of inlet duct positions and highlighting that as ventilation air passes through a space it accumulates increasing levels of pollutants. Section 3.6 notes that amount of ventilation to control winter IAQ may be a tenth of that needed to provide summer cooling (and during winter unoccupied periods even less ventilation may be desirable). It warns in section 3.6.5 that suitable, representative, IAQ sensor locations may be more difficult to find in naturally-ventilated buildings than in mechanical ventilation extract ducts. There is a useful example of applying 'reservoir' capacitance to maintain IAQ in section 4.5.

- **CIBSE AM11 (2105) 'Building Performance Modelling'**

Section 4.6.6 notes the challenge of modelling natural ventilation (and so IAQ) when the building users have control of the openings. It discusses how this can compound the uncertainty in modelling performance. Chapter 6, 'Ventilation Modelling' provides an extensive account of the techniques, tools and applications that can provide that modelling including simple tools and estimation techniques, analytical methods, zonal network methods and CFD.

- **CIBSE TM21 (1999) 'Minimising pollution at air intakes'**

Although nearly 20 years old, still maintains currency in its underlying physical descriptions and overview of the impacts of poor IAQ. Section 4 examines how to estimate the effect of external pollutants on indoor air quality that takes account of the room effects including room air recirculation, the reservoir effect and ventilation effectiveness.

- **CIBSE TM24 (1999) 'Environmental factors affecting office worker performance'**

Contains a brief section 4.3.4 on indoor air quality and air movement although the case studies are now somewhat dated.

- **CIBSE TM26 (2000) 'Hygienic maintenance of office ventilation ductwork'**

Highlights the difficulty defining absolute standards for air quality in terms of the numbers of either fungal or bacteria present in indoor air and cautions these must be treated with caution as there are little data on the health implications of exposure at these levels. This TM includes protocols for microbial sampling and measurement inside ductwork and the occupied spaces to provide early warning of changes that may adversely influence air quality. Although it refers to the now long redundant HVCA TR/17 document (replaced by BESA TR/19) it still provides useful background information (but specific limit data should be cross-checked with more recent publications).

- **CIBSE TM30 2003 'Improved life cycle performance of mechanical ventilation systems'**

Notes that as filters age there is likely to be a reduction in air quality (as well as increased fan power). Generic ventilation systems are compared in section 3.2.3 confirming earlier Guide advice that appropriate installations of displacement ventilation have superior ventilation effectiveness and so can improve the value of a scheme.

- **CIBSE TM36 (2005) ‘Climate change and the indoor environment’**

Predicts that for spaces like classrooms high fresh air ventilation rates required to maintain good air quality means that as the external air temperature increases, it becomes increasingly difficult to achieve comfort standards through use of passive systems alone.

- **CIBSE TM40 (2006) ‘Health issues in building services’**

Chapter 4 provides one of the most consolidated collections CIBSE references for air quality related to ventilation. It considers aspects of legal (as at 2006), physiological, environmental, anthropogenic impact, occupational and security as related to the determination and control of air quality as well as offering practical calculations to determine the rate of fresh air.

- **CIBSE TM53 (2013) ‘Refurbishment of Non-domestic Buildings’**

Lists typical failures in existing buildings including limited cross flow in naturally ventilated buildings due to enclosed spaces, changes to the building layout and building services (HVAC) being no longer fit for purpose resulting in poor air quality and cites this as one of the largest potential sources of occupant dissatisfaction. It also indicates that night purge ventilation can improve air quality for the following day and can represent an important measure to strengthen the case for retaining a natural ventilation strategy for both naturally ventilated and mixed mode buildings.

- **CIBSE TM55 (2014) ‘Design for Future Climate: Case Studies’**

The impact of changing climate of the effectiveness and thus IAQ pervades all of the models.

- **CIBSE TM57 (2015) ‘Integrated school design’**

Confirms that poor indoor air quality in learning spaces not only affects the health and comfort of pupils, but can also impair learning performance and increase absenteeism. It reports that older windows often have poor airtightness, so providing higher infiltration rates and, often, improved IAQ whereas modern buildings have much better airtightness, which can lead to a marked rise in CO_2 levels. ‘Traffic light’ air quality indicators can be used to indicate when windows should be opened to improve IAQ.

- **CIBSE KS17 ‘Indoor Air Quality and Ventilation’**

Provides a very accessible source of assembled information taken from the CIBSE Guides, TMs and AMs and augments this with a list of regulations and standards affecting IAQ and additional material on measuring ventilation and IAQ.

- **Recent CIBSE Journal articles - http://www.cibsejournal.com/**

2015, October p43, ‘Build tight, ventilate right?’
2017, January p30, ‘Clear for take-off? – IEQ –at air traffic control’
2017, January p47, ‘Delivering good building IAQ CPD module’
2017, February p20, ‘Helping everyone breathe easier’

2017, April Supplement p10, ‘Raising standards - How CO_2 limits and flow rates for schools have evolved’

- **Recent BSER&T Papers - http://cibse.org/knowledge/technical-journals/technical-journals-bsert-lr-t**

‘An indoor environment evaluation by gender and age using an advanced personalized ventilation system’ Ferenc Kalmár, 5 Apr 2017
‘The effects of wind velocity and building geometry on air change efficiency in light shafts: Case studies’ Miguel Ángel Padilla-Marcos et al, June 1, 2016.
‘Using coupled energy, airflow and indoor air quality software (TRNSYS/CONTAM) to evaluate building ventilation strategies’ W Stuart Dols, et al, December 9, 2015.

- **Recent Technical Symposium papers - http://cibse.org/symposium**

2016 Rajat Gupta "Monitoring energy and environmental performance of an innovative low energy refurbishment of a historic council office building"
2016 Owen Connick "Zero energy retail Ð a breathing building for Costa Coffee"
2017 Tom Lipinski "Passive ventilation with heat recovery in an urban school: performance in use"
2017 Haniyeh Mohammadpourkarbasi "Business case for exceeding Greater London Authority energy plan"
2017 Linda Lee "Room-based active UV-C technology reduces the amount of bacteria and/or fungus in the air and improves indoor air quality"
2017 Sergio Fox "Learning from the masters: Resilience needs simplicity, and simplicity needs knowledge"

- **Recent Podcast - http://www.cibse.org/news-and-policy/cibse-podcast**

#Build2Perform: The air we breathe – Podcast - https://soundcloud.com/build2perform/the-air-we-breathe

- **CIBSE Groups and Societies - http://www.cibse.org/networks/groups & http://www.cibse.org/networks/cibse-societies**

NOTE – this is a difficult area since there is no traceable QA on group/society events plus there is no consolidated list of events available. There are likely to be many group/society events that touch on IAQ.
Resilient Cities Group - http://www.cibse.org/networks/groups/resilient-cities/past-events-and-presentations
Breathe easy: engineering air quality solutions 21 October 2016
ILEVE – Improving workplace air quality - http://www.cibse.org/institute-of-local-exhaust-ventilation-engineers-i